本文引用格式 / PLEASE CITE THIS ARTICLE AS

Macera, M., De Meulder, B., & Shannon, K. (2020). New Paradigms of Territorial Planning and (Post) Mining Ecological Restoration in the Andes. Landscape Architecture Frontiers, 8(1), 26-41. https://doi.org/10.15302/J-LAF-1-020021

https://doi.org/10.15302/J-LAF-1-020021 收稿时间 RECEIVED DATE / 2019-12-01 中图分类号 / TU984 文献标识码 / A

安第斯山脉地区国土规划与（后）矿山开采生态修复的新范式

NEW PARADIGMS OF TERRITORIAL PLANNING AND (POST-)MINING ECOLOGICAL RESTORATION IN THE ANDES

玛格丽塔·马萨罗
比利时鲁汶大学工程科学学院建筑系都市主义与建筑研究小组博士候选人

布鲁诺·德·缪德尔
比利时鲁汶大学工程科学学院建筑系都市主义与建筑研究小组城市化专业教授

凯利·香农
比利时鲁汶大学工程科学学院建筑系都市主义与建筑研究小组城市化专业教授

Margarita MACERA
PhD Candidate, OSA Research Group, Department of Architecture, Faculty of Engineering Science, KU Leuven

Bruno De MEULDER
Professor of Urbanism, OSA Research Group, Department of Architecture, Faculty of engineering Science, KU Leuven

Kelly SHANNON*
Professor of Urbanism, OSA Research Group, Department of Architecture, Faculty of Engineering Science, KU Leuven

*Corresponding Author
Address: c/o KU Leuven, Faculty of Engineering Science, Department of Architecture, Kasteelpark Arenberg 1, 3001, Heverlee, Belgium.
Email: kelly.shannon@kuleuven.be

摘要

本文认为有必要对拉丁美洲安第斯山脉矿山开采的生态修复工作建立新的范式。文章首先以批判性的视角梳理了矿区和采矿定居点之间超越地域空间上的联系，并揭示了二者在长期生态破坏恶性循环中的矛盾关系。该研究聚焦秘鲁安第斯山脉波托西、万卡维利卡、瓦尔加约克和卡哈马卡这4个采矿定居点背后的地域逻辑，以及它们从18世纪至今的发展历程。这4个定居点成为了当地景观基础设施和水源地资源的一个延伸网络，它们都已经（并将持续）受到采矿活动的明显干扰，遗留下来的不仅是采矿后的有害生态环境，还有不断产生的酸性开采废水。呈现在世人眼前的生态失衡证据表明，即使停止采矿活动，其影响仍会延续数百年。本文根据秘鲁现有立法，反思了当前的后矿山开采景观的修复实践。最后，研究呼吁采取新的国土规划方式，并基于更新对后矿山开采景观的了解和认识，为卡哈马卡制定综合性的设计策略。此类规划需要调和采矿、环境工程和生态自可持续性等之间的冲突，而谋略性的设计研究将为其提供重要支持。

关键词

景观设计；后矿山开采景观；生态修复；安第斯山脉；瓦尔加约克；卡哈马卡

ABSTRACT

The paper argues for the necessity of a new paradigm of ecological restoration in the face of mining extraction in the Latin American Andes. It begins with a critical reading of the extra-territorial connections between mining sites and settlements and unfolds their ambivalent relations through chronic cycles of ecological destruction. The analysis focuses on the territorial logics embedded in four mining-settlements of the Peruvian Andes and their development from the eighteenth to the twenty-first century. Potosí, Huancavelica, Hualgayoc, and Cajamarca form part of an extended network of landscape infrastructures and headwater resources, all of which have been (and continue to be) significantly disturbed through mining operations. The sites have inherited a relentless production of Acid Mine Drainage in addition to other hazardous post-mining ecologies. Tangible evidence of ecological misbalance demonstrates the enduring impact of past-mining activities even centuries after mineral extraction has ceased. The paper reflects on present-day practices of post-mining landscape restoration in accordance with current Peruvian legislation. It concludes with a plea for a new form of territorial planning as well as both the conception and perception of post-mining landscapes through inclusion of design strategies for Cajamarca. Such planning needs to reconcile the contradictory elements of mineral extraction, environmental engineering, and self-sustainable ecological development. Intelligent design research is a major support for such an endeavor.

KEYWORDS

Landscape Design; Post-Mining Landscapes; Ecological Restoration; Andes; Hualgayoc; Cajamarca

编辑 田乐 **翻译** 田乐 李慧彦
EDITED BY Tina TIAN **TRANSLATED BY** Tina TIAN LI Huiyan

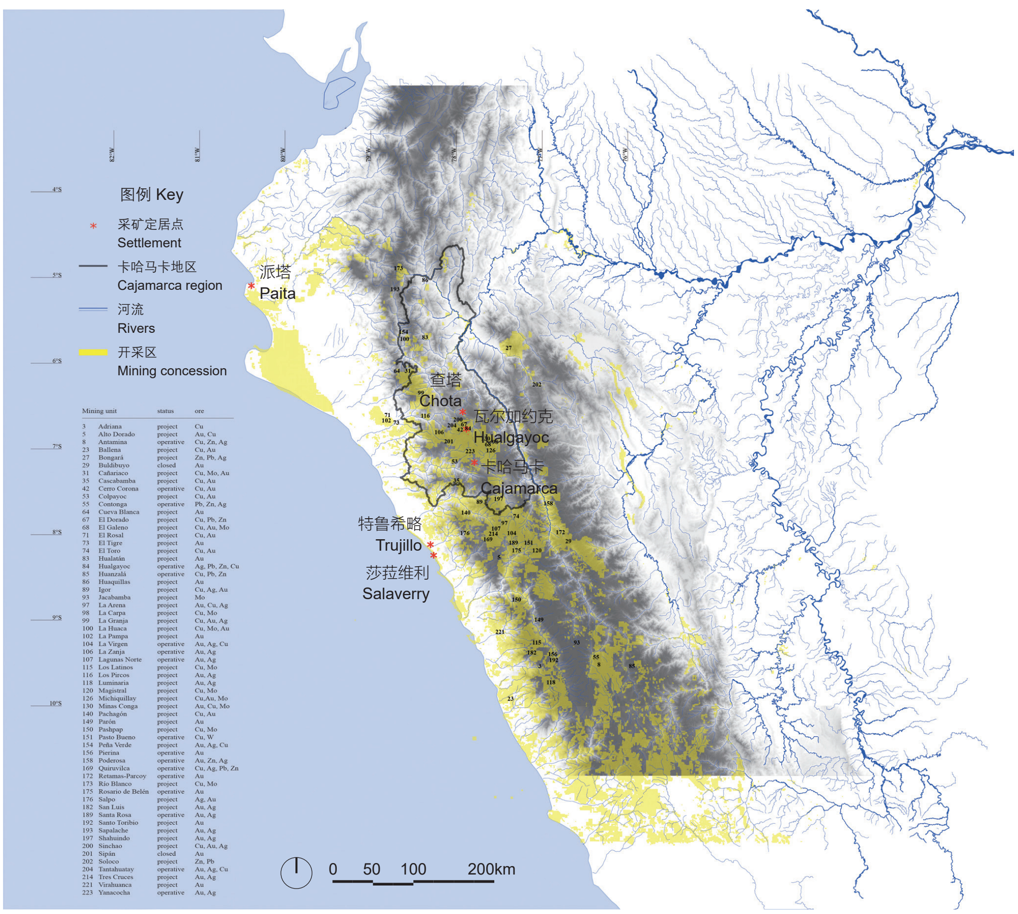
1 引言

采矿业为包括城市化在内的全球消费提供了物质原料。20世纪，近30亿人口迁入城市，大大增加了对住房、食物、淡水和基础设施的需求[1]。在可行的替代方案问世之前，建造业仍将依赖金属原料供应[2]，这就会间接地加剧矿山所在地景观的破坏。为了保持持续增长，采矿业不断追求产能的提高。在国际金融机构和新自由主义采矿法案的支持下，全球对金属原料的巨大需求以拉丁美洲安第斯山脉的采矿投资为代表[3]。早在16世纪，采矿企业就已经在安第斯山脉开采出了“世界级”的矿藏。今天，随着世界各地的城市的持续扩张，更多的矿场开始作业，同时也有一些矿场随着国际市场价格波动和技术进步而不停地在停工或复工间摇摆。

随着挖掘效率的提升和低质矿石加工产业的兴起，安第斯山脉的经济开采作业不断增加[4]（图1）。现场浸出技术的进步使得对小型有色矿石的热力冶炼向湿法冶炼转变，导致采矿业的用水量急剧增大[5]。为了获得用水特权，开采者常常将矿场设在水源地附近。因此，用水管理流程已成为开采过程中不可或缺的一环，且对下游的水质和水量有着切实影响。矿场的生命周期不可避免地会影响其与下游人类聚落的关系——彼此相互依赖但又相互竞争，尤其是涉及水问题时。

2 波托西、万卡维利卡、瓦尔加约克和卡哈马卡：矿山与聚落的共同演变

很多聚落因矿山开采得以建立和发展[6]，但同时也使得大规模的生态破坏日益严重。可以说，采矿业或直接或间接地塑造了城市环境。首先，偏远地区的资源开采所需的主要资本就是人力，只要这里的矿石开采不停息，矿区定居点便会一直存在，而此处的环境通常并不适宜人类聚居。据此，长久以来，安第斯山脉上的开采者都巧妙地挖掘着分布在不同生态层（不同海拔高度的地区，生态条件也不同）的矿



1 © M. Macera, 2018

1. 开采特许权在卡哈马卡地区不断扩大，一度延伸至亚马逊流域和太平洋流域的水源地和人类聚落。大多数特许权中都包含针对那些有待开采项目的勘探权限。

1. Mining concessions increasingly expand over the Cajamarca region and overlap with water sources and settlements of both Amazonas and Pacific watersheds. Most of the concessions accommodate exploration, namely potential mining projects that await to be exploited.

1 Introduction

Mining provides the materials for worldwide consumption, including urbanization. In the 20th century, nearly three billion inhabitants have moved into cities, significantly increasing the demand for shelter, food, fresh water, and infrastructures[1]. Until the development of feasible alternatives, construction will keep relying on the provision of metals[2] and there will be the continued collateral destruction of remote landscapes of extraction. Mining industries incessantly improve productivity in order to stay ahead of growth. Supported by international financial institutions and neoliberal mining codes, mining investments in the Latin American Andes play a crucial role in quenching the worldwide thirst for metals[3]. Already since the sixteenth century, mining enterprises in the Andes have extracted "world-class" mineral deposits. Today, as cities around the world continue to expand, more mines begin operation, while others imminently stop or are reactivated in line with the rhythms of world market prices and technological progress.

Due to a higher efficiency of excavation and low-grade ore processing, an increasing number of Andean sites are economically exploited[4] (Fig. 1). In-situ leaching techniques, employed for the profitable processing of dispersed nonferrous ores, have led to a shift from pyro-metallurgy to hydro-metallurgy, positioning mining as a direct user of water[5]. The strategic location of extraction sites in headwater landscapes allows their privileged access to water. Consequently, water management procedures have become an integral process of extraction, with a tangible impact on the quality and quantity of downstream water. The lifecycles of extraction sites inevitably condition their relationship to downstream settlements, one of mutual dependency but also competition — particularly in relation to water.

2 Potosí, Huancavelica, Hualgayoc, and Cajamarca: Co-Evolution of Mines and Settlements

Mining enables the establishment and growth of settlements[6], while exacerbating large-scale ecological destruction. Mining, explicitly and inexplicitly, generates urban environments. Initially, mining settlements owed their existence to the perpetuity of the productive cycles of extraction in remote landscapes. They required the primary capital for resource extraction, namely human labor. The physical proximity to mines characterized the settlements. They emerged where resources were found, commonly in areas that did not necessarily have the locational assets to host human agglomerations on

藏资源，因而他们的定居点也散布于山脉各处。然而，西班牙的殖民者以及他们的开采方式却从根本上破坏了这种分散的聚落分布形态。

首批所谓的安第斯山脉“采矿定居点”可追溯至16~19世纪西班牙殖民时期[7]。他们将当地原本自给自足的采矿模式转变为工业化开采，在将矿石原料带向世界市场的同时也充实了大洋彼岸的帝国国库。与同时期的其他殖民城市不同，安第斯山脉的开采者们一旦确认了矿藏地点，便会立即建立采矿定居点，而西班牙当局政府往往后来才会将这些定居点正式确立为城市[8]。众所周知的波托西和万卡维利卡定居点正是形成于这一时期，它们只是冶金热潮的产物，虽然建成后得到了官方认可，却缺乏城市规划的指导。它们的出现证明了“先行动再思考、先牟利再负责”的荒谬性。在定义层面上，采矿定居点不同于理性开发的普通城镇那样旨在创造长期的、依靠剩余价值积累来提供资金支持的服务，在波托西和万卡维利卡定居点，采矿产生的剩余价值几乎第一时间即全部外流，故而其建造并未从长远投资的角度出发——简言之，矿区的开发条件极为受限，这也是它本身最大的问题。然而，尽管殖民采矿定居点的地理位置偏远，但随着时间推移，它们还是不免受到本地、区域和全球变迁的影响[9]。鉴于不断交战的西班牙帝国无止境的财力需求，这些矿区的作用和重要性已不言而喻。

玻利维亚的波托西市坐落在塞罗里科山山麓，位于安第斯山脉的银锡矿藏带内。波托西的年降水量稀少，蒸发量大，年气温在零下16° C到7° C之间，这样的严酷环境对于人类居住和采矿而言都非常艰难。波托西和塞罗里科（海拔分别为4 000m和4 700m）处于一个发源于皮科马约河流域的湖泊与支流网络之中。波托西的第一批定居者的水源正是这些季节性河流[10]。然而，除了高强度的开采作业（矿石磨削所需的能源），与之相随的城市发展（人类消耗）也需要从皮科马约河上游源头引水[11]。因此，当地开挖了32个人工湖来补充天然水源，以满足132个磨石厂的作业需求及当地居民的生活需求。1621年，随着位于定居点和矿区东南方向7~15km处的波托西人工湖网络的完工，湖泊、水渠、堤坝、运河、隧道、道路和桥梁对该地区的综合影响远远超出了矿区和城市的范围。

秘鲁境内的圣塔芭芭拉矿区（现已被列入联合国教科文组织世界遗产）位于波托西东北1 000km处，海拔4 400m，该矿区为波托西的银矿加工提供了必需原料——汞（水银）。而在矿场以南2.5km，海拔

their own. Traditionally, Andean settlements were dispersed in order to cleverly exploit locational assets that were distributed over different ecological floors (areas with different ecological conditions that correspond to variations in altitude). Spanish colonization — and colonial mining — radically distorted this dispersed settlement pattern.

The first so-called “mining settlements” of the Andes were a colonial product of the 16th to 19th century Spanish regime[7]. They transformed indigenous mining practices, which served local needs, into industrial-scale exploitation. They supplied the world market and fueled imperial treasuries across the ocean. In contrast to other colonial cities of the time, mining settlements emerged immediately following the identification of mineral deposits, often before they were officially established by Spanish authorities as cities[8]. The well-known settlements of Potosí and Huancavelica are emblematic examples of environments which were instantly generated by metal fever and only subsequently officially recognized, let alone rationally planned. They appeared as proof reductio ad absurdum of acting before thinking, satisfying greed before taking responsibility. The mining settlements were, by definition, at odds with ordinary town development rationality where services are created for permanent use and financed through accumulated surplus value. Potosí and Huancavelica were created without a perspective of permanent investment. All generated surplus value was, as a rule, exported as quickly as possible. In short, mining initiated an impossible development condition, which also explains their inherent problematic nature. Nonetheless, although they were based in geographically remote areas, colonial mining settlements converged over time with local, regional, and global processes of translocation[9]. Their role and importance are self-evident, given the never-ending silver and gold hunger of the ever-warring Spanish empire.

The city of Potosí (in Bolivia) emerged at the foothills of the Cerro Rico Mountain within the tin-silver belt of the Andean Altiplano. Scarce yearly precipitation, great evaporation, and an annual temperature ranging from -16 °C to 7 °C made Potosí a challenging environment for both human occupation and mining. Potosí and Cerro Rico (at 4,000 and 4,700 meters above sea level, respectively) belong to a larger hydrological system of lakes and tributaries of the Pilcomayo Basin headwaters. The first settlers of Potosí relied on seasonal springs[10]. However, mining intensity (ore-grinding energy) and accompanying urban development (human consumption) required the use of headwater sources in the upstream part of Pilcomayo[11]. The construction of 32 artificial lakes — which complemented natural ones — allowed 132 mills to be powered and supply local populations. Potosí’s network of human-made

3 680m处，这里的首个采矿定居点万卡维利卡于1563年建成。相较当时其他的安第斯山脉城市（卡哈马卡，海拔2 750m；阿雷基帕，海拔2 350m；阿亚库乔，海拔2 700m），万卡维利卡和波托西都高于人类定居点常见的海拔高度[7]。

分散建立在万卡维利卡地区的临时性村庄表明当时存在季节性农耕及朱砂（化妆品原料）开采活动。在西班牙殖民时期，万卡维利卡还未有人烟[12]。然而，圣塔芭芭拉的矿山开采使得当地的定居点呈爆炸式增长，这些聚落依赖其他资源来满足居民生活及开采需求。食品和物品的采集来自于方圆450km内的多个生态层，包括来自利马（海拔120m）的布匹和工具、来自纳斯卡（海拔560m）的酒、来自万塔（海拔2 640m）的古柯叶和蔬果、来自阿亚库乔（海拔2 750m）的面包和来自安达韦拉斯（海拔2 890m）的糖。因此，开采业与当地山脉生态环境的严重破坏密切相关。例如，由于万卡维利卡就地熔炼水银需要大量木柴，导致生长在海拔3 500m以上的安第斯山脉典型的秘鲁茅草（*Stipa Ichu*）草原，以及龙鳞木林的显著退化[7]——这不仅是对矿石的开采，也是对区域资源的无情掠夺。

在安第斯山脉北部的热带地区，位于卡哈马卡地区的瓦尔加约克矿区则是秘鲁殖民时期环境破环的罪魁祸首。瓦尔加约克海拔3 500m，位于马拉尼翁河流域。在18世纪70年代初，瓦尔加约克已显现出典型的分散殖民开采模式[13]。瓦尔加约克的矿脉"比赛罗里科的矿脉更丰富，且更易开采"[14]，因此造就了吸引众多西班牙投资者的区域经济。即便是位于瓦尔加约克银矿附近的海拔高达4 000m、阴冷多风、"不宜人居"的山谷中，仍然出现了采矿定居点[14]（图2）。瓦尔加约克与该地区的主要居民聚集区——包括查塔（银加工）、卡哈马卡（食品

2 © Paz Soldán, M. F., 1865

2. 早期的定居点出现于瓦尔加约克山脚下，沿瓦尔加约克河而建。由于建造材料稳定性较差，这些定居点曾多次经历火灾（1798年、1856年和1928年）、破坏和重建。

2. Early settlements rose at the feet of the Hualgayoc Hill, along the Hualgayoc River. Due to their precarious materials, Hualgayoc's settlements were struck by numerous fires (in 1798, 1856, and 1928) and multiple processes of dislocation and reconstruction.

lakes, completed by 1621, was located from seven to more than fifteen kilometers southeast of the settlement and mining hill. Altogether, lakes, aqueducts, dams, canals, tunnels, roads and bridges altered the territory far beyond the mining sites and city.

The mines of Santa Bárbara (in Peru and now a UNESCO World Heritage), one thousand kilometers northeast of Potosí and 4,400 meters above sea level, provided the necessary mercury (quicksilver) for Potosí's silver processing. Huancavelica's first mining settlements rose in 1563, 2.5 kilometers south of the mines at 3,680 meters above sea level. Compared to other Andean cities of the time (Cajamarca at 2,750, Arequipa at 2,350, and Ayacucho at 2,700 meters above sea level), Huancavelica — as Potosí — was located above the usual altitudinal range for a human settlement[7].

Evidence of scattered villages for temporary occupation in Huancavelica indicated the seasonal practice of agriculture and cinnabar-mining activities for cosmetics production. Huancavelica was uninhabited at the moment of the Spanish occupation[12]. However, exploitation of Santa Barbara's mines turned the region into nuclear-like settlements, which relied on other resource niches to cover its urban and mining demands. Food and goods were sourced from a wide range of ecological floors up to a distance of 450 kilometers away. Cloth and tools came from Lima (120 meters altitude), liquor from Nazca (560 meters altitude), coca leaves, fruits, and vegetables from Huanta (2,640 meters altitude), bread from Ayacucho (2,750 meters altitude), and sugar from Andahuaylas (2,890 meters altitude). Mining endeavors went hand in hand with the rampant destruction of local Andean ecologies. For example, in-situ smelting of mercury in Huancavelica required massive amounts of firewood, which led to the significant retreat of local *Stipa ichu* pastures (a typical vegetation of the Andes which grows above the 3,500 meters altitude) and Quinual trees[7]. Mining was not limited to ore extraction; it implied a ruthless seizure of regional resources.

In the northern tropical Andes, Hualgayoc (in the Cajamarca region) has the most significant environmental liabilities caused by colonial mining in Peru. Hualgayoc — located at 3,500 meters above sea level — belongs to the Marañon watershed. By 1771, Hualgayoc represented a dispersed model of colonial extraction[13]. Hualcayoc's mineral veins were "richer than those of Cerro Rico and simpler to extract"[14] and generated a regional economy that attracted many Spanish investors. The mining settlements of Hualgayoc emerged near the Hualgayoc silver hill — up to 4,000 meters above sea level — and in the Hualgayoc Valley, despite the "inhospitable" cold, humid, and windy climate[14] (Fig. 2). Hualgayoc formed part of a larger

和物品供给）、特鲁希略（银条制造及运输）和万卡维利卡（水银供应）——以及其他位于较低生态层的地区，共同形成了一个更大的政治经济体[15]。

瓦尔加约克矿场由沿18条已知地下银矿脉分布的4 000个矿口组成[16]。劳动力召集及饮食保障是殖民时期拉丁美洲开采业面临的主要问题。采矿技术既不依赖密集的资本投入，也无需集中建设作业区。因此"投资者"纷涌而至，大量矿口不断出现。米库伊班帕、埃尔普尔加托里奥和拉庞塔定居点正是为了容纳劳动力而建。其中，米库伊班帕定居点分布于瓦尔加约克山脚下的山谷两侧，犹如矿区的一道大门[17]。截至18世纪末，米库伊班帕的矿工已达三四千人，并就地取材利用茅草建成了约400间"茅屋"[16]。

因对生态和社会造成的灾难性后果，在大规模开采的早期阶段，采矿即一度备受争议——贪婪榨取是资本主义发展的本质，也是造成社会不公及环境破坏的根源。因此，作为瓦尔加约克地区的（启蒙运动）改革典范，由西班牙巴尔塔扎尔・杰米・马丁内斯・科姆潘恩主教提出的"洛斯多斯卡洛斯计划"（尽管这一计划在当时被认为是空想）应运而生。该计划试图通过彻底改善当地恶劣的生活和工作条件（始终寻求快速获益的西班牙殖民政权此前对之视而不见）来提高劳动效率：瓦尔加约克定居点将被洛斯多斯卡洛斯定居点所取代，并对本地工人的土地使用权、工时轮换以及建于巴马卡平原附近的住房设施进行了规定[18]；矿工不再仅限于单身男子，而是以家庭为单位，可以交替从事开采和农业等经济活动。马丁内斯主教详尽地描绘了该计划所涉及的动植物、地质、人文等方面的内容，并配以插图（千余幅水彩画），可以与亚历山大・冯・洪堡的当代安第斯山脉调查相媲美。除此之外，马丁内斯主教还借助科学文献研究加强了计划的可行性，包括详细说明可以种植哪些植物、饲养哪些动物、利用哪些建筑材料等。通过战略性地利用现有人力和自然资源，他规划了如何从功利主义的单纯利润驱动型的人 – 地过度开发转向基于环境整体性的开发，阐述了如何使自然成为文化和城市的一部分，以及自然的主要资源具体将从何处获取。不出意料，瓦尔加约克的主要矿业投资者蓄意破坏了这一计划。尽管如此，在1792年矿产达到顶峰后，瓦尔加约克的产量便逐步缩减，并于1804年废弃。时至今日，可行性和市场逻辑仍是对自然和人类无情剥削进行改革的重要影响因素。将土地和人力资源转化为一种文化（人居环境下的产物，而非对自然的复制）是这一夭折的改革计划不可或缺的一部分。

两个世纪后的1993年，卡哈马卡市建立了大型露天矿场——亚纳科查金矿（海拔3 500~4 150m，位于卡哈马卡流域水源地）（图3）。正如瓦尔加约克一样，亚纳科查的堆浸矿场破坏了安第斯山脉地区特有的、位于3 500m之上永久雪线之下的热带生态系统（图4）。原本这里的植被和厚厚的表层土可以吸收并贮存水分，从而滋养当地流域的含水层和支流[19]，以及位于克丘亚生态层（海拔2 500~3 500m）的河

political economy that involved the main urban agglomerations of the region, including Chota (for silver processing), Cajamarca (for providing food and goods), Trujillo (for the fabrication and shipping of silver bars), and Huancavelica (for providing mercury), and other regions located at lower ecological floors[15].

The Hualgayoc mining works consisted of four thousand mine-openings along eighteen known underground silver veins[16]. As so often in colonial Latin America, assembling and subsequently catering to a major labor force was a primary issue. Mining technology was neither capital intensive, nor that advanced to require centralization of working sites. Hence the multitude of "investors" and mine-openings. Micuypampa, El Purgatorio, and La Punta, were established in order to accommodate laborers. Micuypampa emerged at the foot of Huagayoc Hill on both sides of the valley and served as the main gate to the working sites[17]. By the end of the 18th century, Micuypampa accommodated three to four thousand miners and around 400 "hovels" made from the surrounding ichu[16].

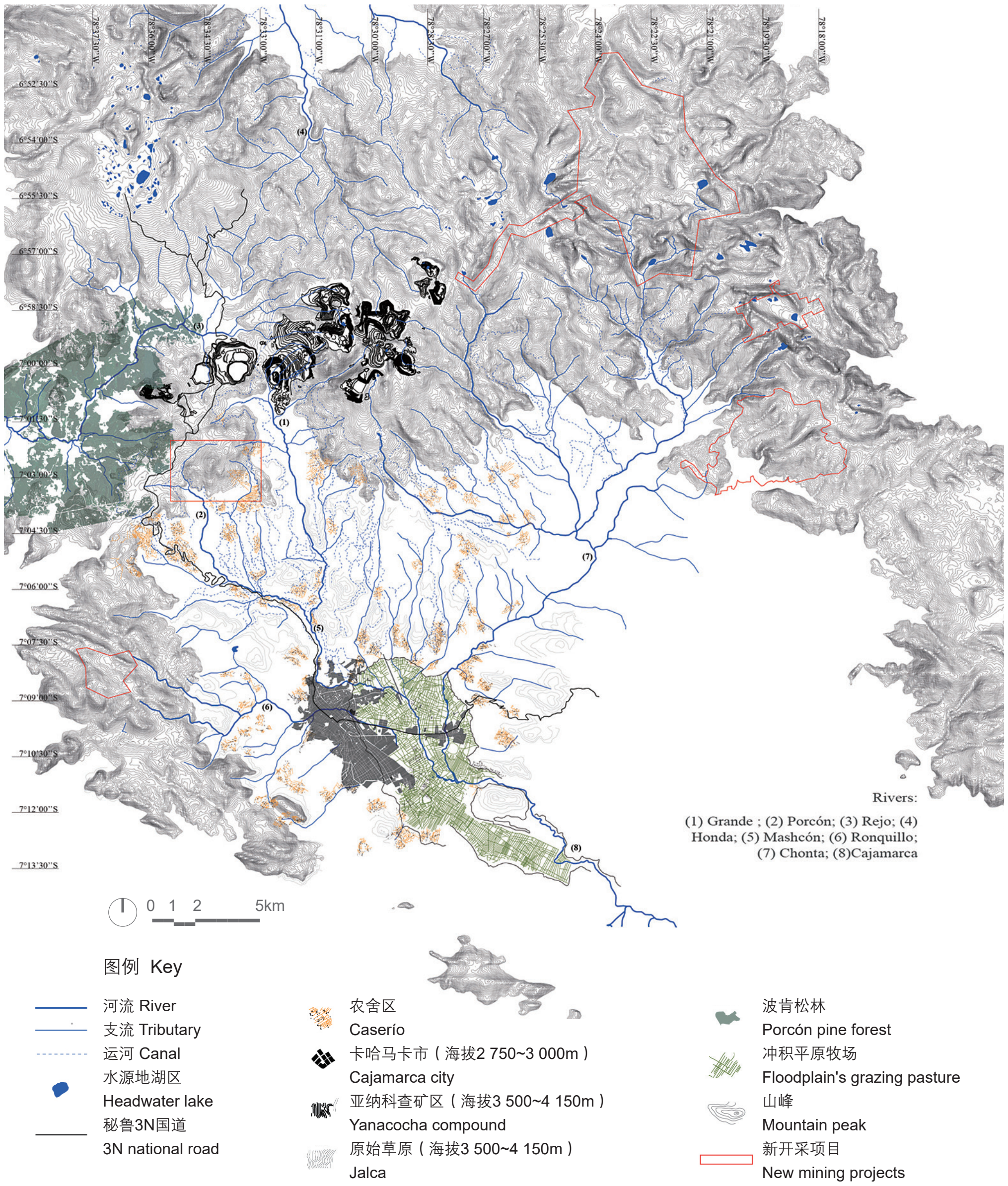
Already at this early stage of mass extraction, mining was heavily contested due to its disastrous ecological and social consequences. Extraction greed appears to be simultaneously at the roots of capitalist development and of an unjust society and damaged environment. At the same time, it should be noted that the Los Dos Carlos project, envisioned by Bishop Baltazar Jaime Martínez Compañon, was exemplary for its reformist (Enlightenment) agenda in Hualgayoc. It imagined the increase of labor efficiency by radically improving the appalling local living-working conditions that the Spanish colonial regime — always looking for greater and quicker revenue — had tolerated. In his vision (then qualified as utopian), the Los Dos Carlos settlement was to replace Hualgayoc and include miner's land-tenures (land tenure for indigenous workers), working hour shifts, and housing facilities in the nearby plains of Bambamarca[18]. In Los Dos Carlos, workers were no longer single men, but included families who were envisioned to alternate work in mining shifts with farming and other economic activities. The extremely elaborated and illustrated (with more than 1,000 watercolors) inventories by Bishop Martinez of fauna, flora, geology, people, and their culture, echo the contemporary Andean surveys of Alexander von Humboldt. However, in this case, his survey also transcends scientific documentation and simultaneously substantiates his project. He detailed which plants were to be used, animals to be raised, construction materials to build, etc. Through the strategic use of available human and natural resources, he projected how to move from a purely profit-driven and utilitarian over-exploitation of people and land to the development of a full environment. He illustrated how to turn nature into culture, into city, and exactly from where nature's primary resources were to

3. 遭受破坏的卡哈马卡流域生态系统。当前，卡哈马卡流域水文环境面临着农村、城市和采矿定居点的巨大用水需求的挑战：开采、生产和生计活动不断争夺着有限的地表水和地下水资源。
4. 金矿开采后，松林逐渐占据了卡哈马卡的荒野。在（通过固碳效益）开发潜在的全球碳市场和（通过提供食用菌、燃料和建筑材料）向农民提供经济回报的同时，松林还会造成较大的地下水消耗以及下游用水成本提高的问题。
5. 卡哈马卡流域使距离遥远但相互关联的亚纳科查矿区（上图）、农舍（中图）和卡哈马卡市（下图）实现了空间上的串联。对水源分配不满的根源在于采矿与其他所有活动之间用水需求的巨大悬殊。

3. Entangled ecologies of the Cajamarca Basin. A simultaneous and intense consumption of water by rural, urban, and mining settlements characterises the hydrological regime of the Cajamarca Basin. Extractive, productive, and subsistence activities compete over same limited sources of surface and underground water.
4. Next to goldmining, pine forests progressively colonise Cajamarca's Jalca. While developing potential global carbon markets (through carbon sequestration benefits) and economic returns to farmers (through the provision of edible mushrooms, fuel and construction materials), pine forests also imply a high cost in groundwater consumption and, therefore, downstream water availability.
5. The Cajamarca Basin circumscribes the distant, but interrelated, domains of the Yanacocha compound (upper), caseríos (middle), and Cajamarca City (lower). Discontent over water distribution is based on the disproportionate demands between mining and all other activities.

be tapped. Not surprisingly, the project was sabotaged by Hualgayoc's main mining investors. Nonetheless, after a peak of mineral production in 1792, Hualgayoc entered a phase of mining retreat. It was abandoned by 1804. Until today, feasibility and market logic arguments resonate through reforms of the ruthless exploitation of both nature and humans. The transformation of land and humans into culture (the production of a human environment rather than the reproduction of a natural one) was part and parcel of the bishop's aborted reform project.

Cajamarca's large-scale surface mining (Yanacocha) was established two centuries later. Gold mining operations started in 1993, at 3,500 ~ 4,150 meters above sea level, in the headwaters of the Cajamarca Basin (Fig. 3). As in Hualgayoc's working sites, Yanacocha's leaching mines invaded the region's unique Jalca ecosystems, a denomination for the tropical Andean ecoregions located above 3,500 meters altitude and below the limits of permanent snow (Fig. 4). Jalca vegetation and thick topsoil absorb and store water, thereby nourishing the basin's aquifers and tributaries[19], well as the rivers of the quechua ecological floor (2,500 ~ 3,500 meters altitude). Since pre-Hispanic times, a vast amount of caseríos (multi-ethnical assemblies of extended-family houses) were dispersed in "vertical archipelagos"[20] across quechua altitudes. The self-subsistence economies of the caseríos rely on reciprocal mechanisms of housing, farming, and water management. The city itself, Cajamarca, lies at the foothills of the Cajamarca Valley — the floodplain of which is believed to have once been an ancient lake[14] (Fig. 5). The Ronquillo,



3 © M. Macera, 2018


4 © M. Macera, 2015


5 © I. Athanasiou, N. Shah, G. van den Bosch, 2018

流。回溯至前殖民时代，大量的农舍（多民族聚居的宗族民居）垂直散布于克丘亚生态层中[20]。自给自足的农舍经济有赖于住房、农业和水管理的相互促进机制。卡哈马卡市坐落在卡哈马卡山谷的丘陵地带，这一带的泛滥平原曾为一个远古湖泊[14]（图5）。隆基略河、波肯河和格兰德河促进了该流域农业和畜牧业等主要经济活动的发展。

在矿石开采和加工方面，尽管亚纳科查高度依赖现有的自动化技术，而非从采矿定居点引入劳动力，但这里仍然拥有一支庞大的劳动力大军（8 000多名工人[21]）。这些矿场在卡哈马卡市以北40km处，且海拔高度又提升了1 250m，已然不适合人类长期居住，更不用说永久居住了。但是卡哈马卡市的地理位置相对优越，配备了引进物资和专业劳动力所需的最基本的基础设施，以确保能将矿石运送至特鲁希略的沿海港口。因此，卡哈马卡就像是“矿区与大都市之间的一个中转站”[22]。在亚纳科查矿区，很少有供短期作业人员居住的临时住房设施[23]，亚纳科查开采企业在城市与矿区间建立了一个庞大的公交运输系统，以组织成千上万名矿工的日常通勤。卡哈马卡的存在使得亚纳科查省去了对定居点的结构性投资。但是，亚纳科查只是单纯享受卡哈马卡所提供的服务，却不愿助力其可持续发展——亚纳科查在卡哈马卡的投资仅限于为贵族学校和医疗设施等提供最低资金支持，而且大部分学校和医院都只向采矿工人及其亲属开放[24]。因此，即便是卡哈马卡，其尚未形式完整的开采产业体系，因为开采活动的固有属性已经决定了这里应当创建一个全面而包容的环境，从而实现人与生态的和谐共荣。

而且，由于亚纳科查矿区的出现，该地区的城市人口从1993年的31.1万人增长至2017年的53.7万人，其中大部分集中于卡哈马卡市[25]。在过去30年间，卡哈马卡的城市建设大肆向山区扩张，这反过来又增加了城市汲取地下淡水的需求。与此同时，亚纳科查的采矿活动也显著改变了当地流域的水资源管理。邻近地表水水源地的地理优势一方面有利于亚纳科查的金矿开采，另一方面法律上也要求矿业公司保护上游水质，并为保障下游居民（包括城市居民和大量居住在分散农舍中的居民）的生计制定流域尺度的供水机制。因此，亚纳科查实际上变相控制了格兰德河和波肯河的水源地，造成该市两家饮用水厂必须依赖于矿业公司才能获得充足水量。为了缓解这一问题，2004年，亚纳科查修建格兰德大堤，以便调节泥沙排放，从而增加城市供水，使该市饮用水的日产量翻番[26]。除了城市供水的集中化和高度工程化，农舍居民还开发了复杂的灌溉系统、精细如迷宫般的运河系统以及能够自给自足的梯田。目前，卡哈马卡及其周围的农舍，以及亚纳科查都在争夺安全使用淡水的特权。这引发了关于小型和大型水系统的争议，这些供水系统也关系到当地、区域和全球的开采战略[27]（图6）。

毋庸置疑，目前的用水商品化政策在资源争夺方面的收效甚微。不过，在过去30年的实践中，围绕水和土地的社会－环境冲突对常规的开采作业构成了威胁，也正是由于这些原因，卡哈马卡北部原始草

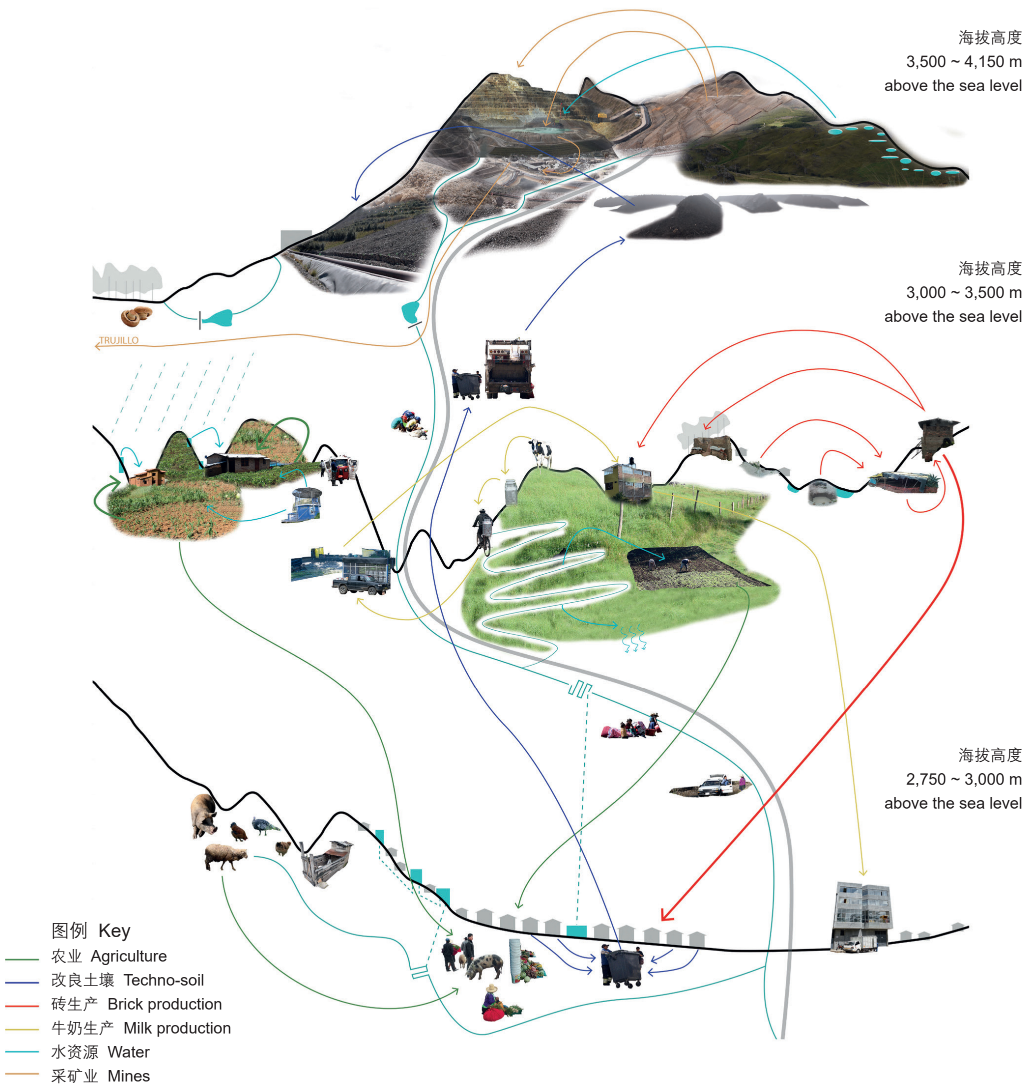
Porcón, and Grande Rivers articulate the primary agricultural and cattle-raising economical activities of the basin.

For the purposes of excavation and ore processing, Yanacocha relies heavily on currently available automated technologies rather than on imported human labor from mining settlements, although the labor force of Yanacocha (of more than eight thousand workers[21]) is still impressive. The mines operate forty kilometers north of Cajamarca City and 1,250 meter higher, hence in areas not proper for long, let alone permanent, human settlement. The city, however, is better located and sufficiently equipped with the minimum infrastructure necessary to import supplies and specialized labor force, and to ensure the transportation of ores to the coastal harbor of Trujillo. Cajamarca serves as a “stepping-stone between extraction sites and bigger metropoles”[22]. Within the Yanacocha compound, very few temporary housing facilities host a “fly-in fly-out,” specialized labor force for short periods of time[23]. The majority of miners are bussed daily from Cajamarca. The Yanacocha mining company developed an impressive city-mine bus transportation that organizes the daily commute of thousands of miners. Cajamarca’s existence allowed Yanacocha to evade structural investment in settlement. Yanacocha rather makes use of Cajamarca, than contributes to its sustainable development. Yanacocha’s investments in Cajamarca are restricted to minimal payoffs for the financing of exclusive schools, medical facilities, etc., most of which only benefit the mining workers and their relatives[24]. One is still far away from a mining industry as an integral and inherent part of its activity produces a full, inclusive environment in which humans and ecology can thrive.

Yanacocha triggered notable demographic growth. The region’s urban population increased from 311,135 in 1993 to 537,000 in 2017, with a large part of that growth concentrated in Cajamarca City[25]. In the last thirty years, the imprint of Cajamarca has abruptly expanded uphill. This, in turn, has increased the demand for pumped, freshwater provisions. At the same time, Yanacocha’s mining has significantly transformed the basin’s water management. Its adjacency to ground and surface headwater sources not only serves the purposes of mining, but also legally requires the mining company to safeguard upstream water quality and develop basin-scale mechanisms of water provision for downstream livelihoods — including both the city and dispersed, but extensive, rural settlement pattern of caserios. The fact that Yanacocha controls the headwaters of the Grande and Porcón Rivers, has created dependency on the mining company for sufficient water flow to the city’s two potable water plants. In 2004, the Grande Dike was constructed to regulate sediment discharge and thereby increase urban water supply, doubling the regular production of the city’s potable water plants[26]. Besides the centralization and heavy engineering of

6. 卡哈马卡矿区中城市、乡村和开采业的协同效应。对于海拔2 750~3 500m的卡哈马卡矿区、城区和乡村地区而言，水既是它们竞争的资源，也是联系的纽带。在整个流域的冲积平原和山脉中，供水使乳业、农业、养殖业和当地砖制造业得以发展。

6. Urban, rural, and mining synergies in Cajamarca. Water is an element of contention and articulation of Cajamarca’s mining, urban, and rural domains, from 2,750 to 3,500 meters altitude. Water provision allows for the development of milk production, agriculture, farming, and local industries of brick production throughout the basin’s floodplains and mountains.



6 © I. Athanasiou, N. Shah, G. van den Bosch, 2018

原的新采矿项目未能获得许可。同时，尽管开采系统的机械化和200余年的劳工立法进程使得开采作业条件和相关社会问题得到重视，但却未能解决采矿所造成的广泛社会危机，特别是当前的土地所有权（开采期限）和环境破坏等问题，进而影响了当地农业社区的生计。从水资源的品质（主要是水质污染）、数量和分配问题中可以窥见矿场与社会、全球与地方行动者、生态与经济之间的种种冲突。社会和环境的不公平正日渐加剧。2010年，亚纳科查试图将其开采范围扩大至卡哈马卡东部的原始草原地区。鉴于潜在的环境影响，当地爆发了大规模的抗议活动，秘鲁政府被迫宣布该市进入紧急状态[28]。在社会–环境问题未能得到解决之前，该项目将被继续搁置。

也是因为水源景观仍然受到开采市场的严重影响，为了保持竞争力，瓦尔加约克和卡哈马卡的矿场都不得不利用新技术来开采品级较低的矿产，并重启矿口和废石堆来勘探那些之前未开采的矿藏。在废弃了两个多世纪之后，瓦尔加约克于2008年开始对（采矿定居点以西2.5km的）塞罗克罗纳山区进行新一轮的密集型采矿投资，这里的露天金矿和铜矿有望持续开采15年[29]。在对这些矿场进行大规模开采

urban water provision, communities of the caserios developed sophisticated irrigation systems with elaborated, fine-mazed canal systems and agricultural terraces (Andenes) that sustained self-subsistence. Presently, Cajamarca, its surrounding caseríos, and Yanacocha compete for the privileged and secure access to fresh water. This results in disputes over small-scale and larger water systems that are connected to local, regional, and global strategies of extraction[27] (Fig. 6).

It goes without saying that the current policies, which allow using water as a commodity, are far from helpful in this respect. However, in an increasing number of cases over the past three decades, socio-environmental conflicts around water and land have challenged business-as-usual mining operations. For this reason, new mining projects in the northern jalcas of Cajamarca have notably failed to materialize. At the same time, although the systematic mechanization of mining and two centuries of labor legislation have brought work conditions and related social issues to the fore, they have not resolved the general social crisis generated by mining. Today, this is evident in issues of land tenure (expropriation by mines) and environmental destruction affects the livelihoods of local farming communities. Water quality (namely pollution), quantity, and distribution underscore the conflicts between mines and society, global and local actors, ecology and economy. There is convergence of social and environmental injustice. In 2010, Yanacocha attempted to expand its operations to Cajamarca's eastern jalcas area. Massive protests against the potential environmental impact forced the Peruvian Government to declare a state of emergency in the city[28]. Until socio-environmental issues are overcome, the project remains on hold.

In Hualgayoc and Cajamarca, headwater landscapes remain at the mercy of market logics. In order to remain competitive, the mines have resorted to the exploitation of lower-grade minerals with new mining techniques, and to the re-mining of openings and waste-piles in search for ores previously not extracted. Since 2008, more than two centuries after its abandonment, Hualgayoc has been undergoing a new cycle of intensive mining investment, this time in the hills of Cerro Corona (2.5 kilometers west of the settlement). The gold and copper surface mines of Cerro Corona are expected to be profitable for 15 years[29]. Their large-scale exploitation runs parallel to prevailing artisanal mining of old and new underground sites in the Hualgayoc Hill. Likewise, since 2007, the Potosí region has also experienced a new cycle of intensive mining for the extraction of low-grade silver, zinc and lead in the surface mines of San Cristóbal[30]. The San Cristóbal mines are located 300 kilometers southeast of Potosí City. As in Hualgayoc, Potosí's large-scale operations co-exist with artisanal exploitation of Cerro Rico's remaining minerals. In the same way, since 1993,

的同时，瓦尔加约克山新旧地下采矿点则继续进行人力挖掘。同样，自2007年以来，波托西地区也经历了新一轮的密集开采，目标是圣克里斯托瓦尔露天矿中的低品级银、锌和铅[30]；在位于波托西市东南方300km处的圣克里斯托瓦尔矿区，大规模采矿作业同塞罗里科剩余矿藏的人力开采并存。自1993年以来，亚纳科查的矿区同样先后经历了开采、扩张和临时关停等阶段。随着采矿计划的多次变更，当地矿场的最终关闭时间一延再延，至今尚无定论。

波托西、万卡维利卡、瓦尔加约克和卡哈马卡等地的矿场一直在开采和关停之间不断摆动，这与人们对于开采业的传统直观的认知不符，它们并非一种有终点的线性活动。对这4个案例地区的历史解读迫使我们重新认识采矿活动，其作业复杂、历时漫长（有时甚至会无止境地持续下去），涉及诸多层面，且具有路径依赖性（类似周期性作业）。这一认知与政策立法相矛盾，后者始终认为采矿是一个简单的短期线性过程，因此对开采后的环境恢复进行了规定。人们认为采矿和生态修复都是线性的过程——有明确的起点和终点——因而在矿区关闭后进行生态修复是轻而易举的事。然而，安地斯山脉数百年的采矿经验表明，对不断累积的有毒污染的治理几乎是一项永久性工作。同样，环境治理过程显然应该和漫长的、阶段性的开采过程同步整合。

3 （后）矿山开采景观的生态遗迹特征

1804年，由于（为处理天然含水岩石的渗水而建造的）排水隧道维护的终止，瓦尔加约克的矿场也随之废弃，然而河谷中废弃矿泥所产生的污染却不断累积。根据秘鲁政府的统计，瓦尔加约克长期的开采作业造成了千余项环境负债，且大部分是露天的酸性开采废水[31]。瓦尔加约克的酸性开采废水严重污染了廷戈－梅加斯班巴河、瓦尔加约克－阿拉斯科格河和佩拉马约河，这些河流都是该地区的主要生态水源。2016年，这三个流域的水源地被宣布进入为期90天的环境紧急状态。在如此短的时间内显然不足以开展深思熟虑的补救行动。接着，2018～2019年划拨了1 550万美元的财政预算，用于继续开展废弃采矿隧道和废石堆的关停和关停后的相关工作[32]。

在瓦尔加约克，尚未完成的生态修复工作包括淹堵成千上万的地下隧道、封闭通风烟囱及设置排水渠。除此之外，还需要在整个排水管道中布置土工织物和石灰石，并常年维护，才能有效中和外流的酸

Yanacocha's mines have faced sequential phases of exploitation, expansion, and temporary inactivity. With mining plans continuously updating, there is no conclusive date for an anyways continuously delayed final closure.

Potosí, Huancavelica, Hualgayoc, and Cajamarca represent a cyclic sequence of continuous mining and temporary closure. This opposes the conventional, as well as intuitive, understanding of mining as a linear, finite activity. The historical reading of these four cases forces the re-consideration of mining as a complex operation executed over very long, nearing permanent periods, layered and path dependent (nearing cyclic operations). This interpretation contradicts policies and legislation that continue to conceive mining as a straightforward, short-lived, linear process, which surely applies for regulations on post-mining environmental restoration. It has been assumed that mining and ecological restoration follow a linear sequence of extraction — with a clear beginning and end — and that simple ecological restoration can be executed immediately after mining closure. However, four centuries of mining experience in the Andes reveal that treatment of accumulated toxic pollution is a near-continuous endeavor. It also is clear that processes of environmental remediation should be more intertwined with the chronic phases of mineral exploitation.

3 Ecological Legacy of (Post-)Mining Landscapes

The abandonment of Hualgayoc's mines in 1804 went hand in hand with the end of maintenance of drainage tunnels (constructed to deal with the natural watery rocks), while pollution generated by the disposal of mining sludge in the river valleys accumulated. According to Peruvian Government inventories, historic mining operations in Hualgayoc left behind more than one thousand environmental liabilities, mostly open sources of acid mine drainage (AMD)[31]. Huagayoc's AMD seriously pollutes the Tingo-Maygasbamba, Hualgayoc-Arascorgue, and Perlamayo Rivers, all of which are main water sources for the region's ecologies. In 2016, a state of environmental emergency was declared concerning the headwaters of the three catchments for a period of ninety days. This limited time was evidently insufficient for a thoughtful remediation venture. A budget of 15.5 million dollars was allocated for 2018 and 2019 to continue closure and post-closure procedures of the abandoned mining tunnels and waste piles[32].

Pending ecological restoration in Hualgayoc include the flooding and tampering of thousands of underground tunnels, the closure of their ventilation chimneys, and the installation of outlet drainage canals. Even with such measures, neutralizing the outflows of AMD requires the implementation — and perennial maintenance — of geo-textiles and limestone throughout all the drainage canals[33]. The

性开采废水[33]。废弃尾矿污染治理需通过物理、化学、水文、生物学等措施进行稳定，其中包括：在尾矿的斜坡上建造石笼[34]，用塑料覆盖粘土、砾石和表土的衬层和连续层来隔离含硫化物[35]；在一些考虑全面的植被恢复计划中，则提倡在引种乡土物种前先对表层土壤施以氮、钾和磷肥[36]；用石灰石管道网络对被覆盖尾矿中的径流进行导流，以便不断中和污水，避免对下游造成污染。

波托西的情况与瓦尔加约克相似，波动的采矿周期也造成了水源的持续污染，弃矿、淹堵、排水和多次复采刺激了酸性开采废水的产生。再加上相互连接的隧道工程和坍塌威胁，使污染源的检测和准确定位愈加困难[37]。长达数百年的有毒排放物严重污染了表层和次表层水、河流沉积物和土壤。瓦尔加约克和波托西是21世纪典型的较大规模的矿山开采实例，酸性开采废水是当地采矿活动的主要遗迹特征。从全球角度看，新矿在“旧矿”的社会－环境遗迹上开展作业，21世纪采矿的挑战与废弃采矿点的环境负债交织并存——这些矿场在被再度利用或生态修复前，将一直处于无人监管状态。

鉴于卡哈马卡的矿产资源已部分枯竭，或采矿堆已达最大储量，生态修复正与当前矿产开采同步进行。而修复措施遵循了标准环境工程方案，主要目的是为防止酸性开采废水的外流，具体包括：阻隔酸性开采废水来源、重塑坡面轮廓，以及（在开采之前进行）表土剥离及储存。最终建立起植被恢复过程，以诱导和加速自然演替和乡土物种的繁衍[38]。当然，这样的修复措施还是无法复原当地的原始草原，因为后者是千万年生态演化的结果。

2000年，亚纳科查的马基马基矿坑实施了部分回填，并中和了部分环境危害。以此为背景，在经过地表重塑的矿坑之上，矿山关停实验中心自2006年起开始运营，着手处理酸性开采废水，并对复原区实施监测和维护[39]。2005年，圣何塞矿坑被改造成了一个水库，用于储存那些处理后的流经采矿设施的地表径流。另外，水库也为矿石加工和

tackling of pollution from abandoned tailings involves different physical, chemical, hydrological and biological stabilization measures. Some of these include the construction of gabions in the slopes of tailings[34] and the isolation of sulphide-containing surfaces with plastic over liners and consecutive layers of clay, gravel, and top-soil[35]. Thoughtful revegetation requires top-soil fertilization with nitrogen, potassium and phosphorus, and the subsequent plantation of native species[36]. Networks of limestone-canals are necessary to divert the runoff from the covered tailings in order to continuously neutralize effluents as they move downstream.

Similar to Hualgayoc, Potosí's oscillating mining cycles have also generated continuous pollution of water sources. Mine abandonment, flooding, dewatering, and multiple re-opening have stimulated a ceaseless production of AMD. Interconnected tunnel works and collapse threats complicate the inspection and accurate location of pollution sources[37]. Toxic emissions over from the last five centuries have severely contaminated surface and subsurface waters, stream sediments and soils. Hualgayoc and Potosí are examples of a typical larger mining context in the twenty-first century, where AMD is a primary legacy of mining activities. In a global perspective, new mining operations co-exist with the socio-environmental legacies of "old mining." The challenges of mining in the twenty-first century intersect with the liabilities of orphan mining sites — sites that will continue to be orphaned until the moment that they are once again exploited or left to return to a second nature.

In Cajamarca, ecological restoration has been carried out simultaneously with ongoing mineral exploitation — when mineral resources are partially exhausted, or the mining heaps have reached their maximum storage capacity. The measures focus on the outflow of AMD. To this end, standard environmental engineering protocols are followed. The measures entail the isolation of AMD sources, re-contouring of slopes and the application of reserved topsoil (stripped and stored prior to mining excavations). The ultimate aim is to trigger a process of a re-vegetation to induce and accelerate natural succession and the re-colonization by native species[38]. It goes without saying that such re-vegetation cannot reconstruct anything close to the original jalca that was the ecological outcome of thousands of years of evolution.

In 2000, a partial backfilling and neutralization of environmental hazards was implemented in Yanacocha's Maqui Maqui Pit. Within this context, a Mining Closure Experimental Centre has been on operation since 2006 in the pit's re-contoured surface, in parallel to the continuous treatment of AMD effluents and the monitoring and maintenance of the

上游运河（这些运河曾经直接从水源地引水）[40]提供了水源。2015年，从拉奎努阿矿坑开采出的物料重塑了其北部废石堆，而作业范围则向南扩展，一直延伸到格兰德河的源头[41]。

酸性开采废水的持续处理与亚纳科查的开采作业同步进行[42]。一系列的运河和管道将酸性水输送到酸性开采废水处理厂——即格兰德水库或圣何塞水库——随后排放到格兰德河或上游运河中，促使经过处理的水重新进入已严重失衡的卡哈马卡水循环系统。今天，下游水质极其依赖这一人工（重新）设计的水源系统，该系统还可以补偿由从矿坑底部含水层抽水造成的下游水流损失。

总体而言，亚纳科查的逐步关停并不妨碍那些仍在进行的采矿活动（图7）。金矿挖掘、浸出、提炼和熔煅等过程产生了成堆的氰化金，并造成了土壤贫瘠、大地满目疮痍。露天矿、堆浸垫层和废石堆成为金矿开采过程中及开采后出现并遗留下来的主要开采特征和地貌。与此同时，整个黄金加工的日开挖量可达50万吨，并需要消耗与之成正比的水资源，因此，随着冶金过程中氰化物和水在堆浸垫层、水库和选矿厂之间的不断循环，水源地的景观与生态正发生着不可逆转的改变[43]。

亚纳科查采矿景观规划和建设的总体目标是在开采地下矿藏的同时，经济而高效地运输或储存开采出的物料。在采矿工程所决定的地形形态和空间分布基底上，生态修复企业负责进行细化设计。具体来说，在堆浸垫层和废石堆的建造过程中，大型挖掘机将爆破后的物料逐层堆填，并以自然休止角度形成台地[44]，且台地的大小由运输设备所决定，而建造位置则以节省运费为原则。矿区规划首先要保证地下矿藏开采的便利性，堆浸垫层和废石堆的置放应与周围地形相协调——据此，上游河谷非常适合以经济的方式堆填物料，因而用河谷堆积方式建造堆浸垫层的做法非常普遍[45]。虽然从表面上看起来这种做法没有破坏自然天际线，但却使山谷丧失了天然的水利功能——卡哈马卡的水源生态系统成为了追求利益最大化的金矿开采作业的牺牲品。这种新的采矿地貌遍布整个草原地区，同时也使当地典型的空间和生态结构严重退化。迄今为止，后矿山修复仍无法逆转空间和生态破碎化的情况（图8）。通过挖掘矿石和处理废石上覆地层，亚纳科查的采矿活动从根本上改变了当地的地质结构和生态环境，相比之下，渐进的修复工作显得杯水车薪[46]。

在瓦尔多约克和卡哈马卡，对水源地景观的不断改造已经对当地及更大的生态系统产生了长期影响。后矿山水源地景观需要常年的人工干预才能保证下游的基本水质。为了重建后矿山生态环境并保证水源地的可持续性，需要处理大量土壤并改变开采过程。瓦尔加约克的经验表明，当开采作业缩减时，对石堆进行彻底重新安置（即二次改变地貌和集水区）的做法成本高昂却收效甚微，地方政府不愿也无力负担[47]。

rehabilitated areas[39]. In 2005, the San José Pit was turned into a reservoir which stores treated water from the runoff of mining facilities. It provides water for ore processing and feeds upstream canals (that were once fed directly from headwater sources)[40]. In 2015, excavated materials from the La Quinua Pit served to re-contour its north rock waste piles, while operations expanded south, towards the headwaters of the Grande River[41].

Continuous mitigation of AMD accompanies Yanacocha's mining excavations[42]. A series of canals and pipes transports acid water to AMD treatment plants — either the Grande Dam or the San José Reservoir. Subsequent discharge to the Grande River or upstream canals allows the treated water to re-join Cajamarca's severely distorted hydric cycle. Today, downstream water quality heavily depends on this artificially (re)engineered headwater system. It is supposed to also compensate for the loss in downstream water flows caused by the pumping of aquifers from the pits' floors.

Overall, Yanacocha's progressive closure activities do not interfere with the ongoing mining exploitation (Fig. 7). Through excavating, leaching, gold-retrieving, and smelting, mining creates artificial mountains of gold-cyanide, sterile soils, and deep cavities. Open-cast mines, leaching pads, and rock waste piles are the primary mining facilities — and landforms — that emerge and remain during and after gold exploitation. At the same time, mining activities irreversibly transform headwater landscapes and ecologies at the pace of half a million tons of earth movement per day, with directly proportional volumes of water harnessed throughout the gold-processing — recycle of cyanide and water among leaching pads, water reservoirs, and mineral processing plants in the recovery of gold[43].

The overarching objective in the planning and construction of Yanacocha's mining landscapes is to access underground deposits and to transport or store excavated materials efficiently and economically. Engineering dictates the geometry and spatial distribution of landforms which are eventually inherited by ecological restoration ventures. In the construction of leaching pads and rock waste piles, large excavators arrange blasted materials in successive layers to form terraces at a natural angle of repose[44]. The dimensions of the terraces are determined by earth-moving equipment. The definition of their location prioritizes the economy of transportation. The planning of the mining compound has to first guarantee immediate access to underground mineral deposits. The placement of leaching pads and rock waste piles responds to the adjacent topography. Upstream valleys have ideal topographic configurations for the economic dumping of material. The construction of leaching pads by means of valley-filling hence became common practice[45]. While satisfying (as general as superficial) concerns about the preservation of the natural skyline,

7. 黄金开采首先需要进行土地爆破和表层土储存：通过在露天矿坑内建立一个或多个水平作业台来开采矿石，同时将爆破后的岩石分别放置于（含矿石的）堆浸垫层或废石堆。
8. 经过地形改造的矿区和原始草原上裸露的岩石、贫瘠的草地共存。矿坑台地和堆浸垫层改变了径流和天然含水层的自然流动方向，而这些却决定了能否保持流域水循环的平衡。

7. Gold exploitation begins with the blasting of terrain and the storage of topsoil. Surface cuts make use of one or more horizontal benches in open pits to extract ores while selectively separating the blasted rocks in (ore-containing) leaching pads or waste rock piles.
8. Disturbed mining areas co-exist with rocky patches of the Jalca and depleted grasslands. Pit terraces and leaching pads re-direct the natural flows of run-off water and natural aquifers which are key to the balance of basin-scale hydric cycles.

7 © M. Macera, 2018

8 © M. Macera, 2019

可以说，当代开采业的社会–环境负债大多是过去几十年甚或几百年间被关停的废弃矿场造成的，这远远早于环境立法的时间。由于资源枯竭、矿石市场价格波动和经济活动向其他地区转移等原因，人们可能在矿场附近突然定居，但也可能一夜之间从矿场撤离[48]，在这一过程中引发了一次次的环境危机。采矿场关闭后，之前定居点的文化、经济和环境恶化仍会持续很久——在大多数情况下，这样的“鬼城定居点”会逐渐成为当地文化遗产的一部分。剩余的矿区则会在被社会遗弃后，经重新自然演化而成为一种特殊的“荒野”景观。

4 （后）矿山开采景观设计新范式

因地点过多且时间过长，安第斯山脉的采矿活动问题重重，备受争议。往往还未开采就已出现争议，被中止开采的卡哈马卡新矿就是一个典型实例。矿山关闭后，为了履行法律义务而开展的一系列环境整治项目常常只是打着生态修复的旗号，实际上仅进行了简单的绿化

this practice distorts the natural hydric function of the valleys. Cajamarca's headwater ecosystems remain a mere leftover from the ground operations to most profitably extract gold. While distributing new landforms across the jalca, mining atrophies its typical spatial and, thus, ecological configuration. To date, post-mining restoration is unable to overturn spatial and ecological fragmentation (Fig. 8). By unearthing ores and disposing waste rock overburden, Yanacocha's mining activities overwhelmingly yield more tectonic landforms and ecologies — than the (progressive) rehabilitation procedures[46].

In Hualgayoc and Cajamarca, the sequential manipulation of headwater landscapes has had long-term consequences for local and larger ecosystems. Post-mining headwater landscapes require of perennial, artificial mechanisms to guarantee minimal quality of downstream water. In order to re-orient post-mining ecologies and to guarantee the sustainability of headwaters, it is necessary to manipulate massive volumes of soil and reverse the process of mineral exploitation. The case of Hualgayoc demonstrates that, at the decline of mining operations, a thorough relocation of heaps, i.e., handling earth for a second time to rectify landforms and watersheds, is both a costly and inefficient endeavor which local governments are unwilling to undertake, and unable to finance[47].

Contemporary socio-environmental liabilities of mining have their origins in closed and abandoned operations from decades or centuries ago, long before the establishment of environmental laws. The hazards prevail alongside mining accommodations and abrupt processes of "unsettlement"[48] due to resource exhaustion, fluctuations of mineral market prices, and the shifting of economic activities to other areas. The cultural, economic, and environmental deterioration of previous mining settlements continues long after mining closure. In most cases, such "ghost settlements" become part of a region's cultural heritage. In other cases, nature reclaims them. Through social abandonment, they become re-naturalized and evolve into a particular kind of "wilderness."

4 (Post-)Mining Design: Towards a New Paradigm

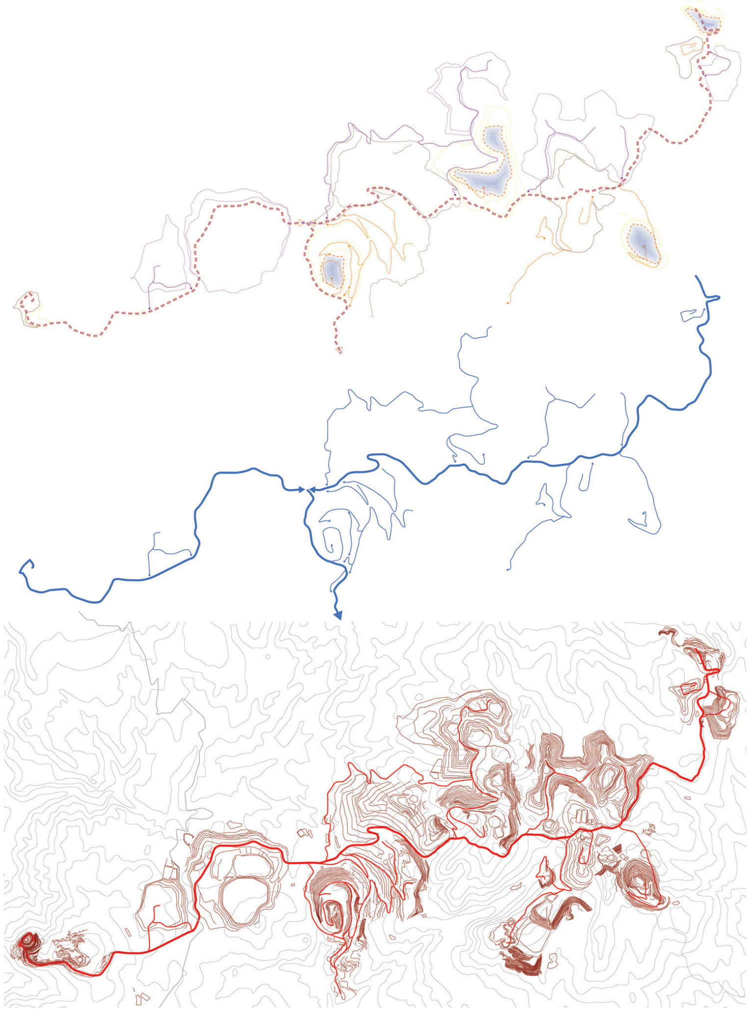
Mining in the Andes is (as in so many places and for so long) highly problematic and heavily contested. Contestation starts before extraction, as emblematically demonstrated in the halting of new mining site openings in Cajamarca. After mining closure, environmental remediation programs are unfolded to comply to legal obligations that aim for a theoretical ecological restoration but, in reality, are mere smokescreens of greening. AMD remains a near-permanent issue — on old mining sites, in the headwaters and all the way downstream. At the same time, contemporary mining becomes more and more complex: it assembles a layered

而已。酸性开采废水从旧矿址的水源地一路流向下游，这似乎仍是无法根治的难题。与此同时，随着法规的不断出台及愈发广泛的社会关注，开采业已成为一个涉及诸多空间和法律因素的日益复杂的体系。

如前所述，矿山开采有其自身的周期特性，而且也必然会对更广大的城乡环境的生态循环产生影响。开采对稀缺水资源的影响和争夺使生态、城市、乡村和采矿的循环过程相互交织。这就是为什么在制定开采政策、方案和项目时，重要的是不能再将矿山开采定义为短期的线性过程（矿场无法在关停之后很快得以恢复），而需要正视其是一个持久的周期性过程——且城市区域内的过程尤为关键。换句话

patchwork, spatially — and legally — as regulations, norms, and socially acceptable expectations accumulate.

As mentioned, mining has acquired its own cyclic characteristics, that unavoidably interfere with the lifecycles of the wider rural and urban environments onto which it imposes itself. The impact of mining on and competition for scarce water resources, intertwines the cycles of ecology, city, countryside, and mining. This is why it is crucial, when developing policies, programs, and projects in mining, to no longer conceptually understand mining as a short-lived linear process — an interruption of the normal that is quickly repaired — but rather de facto recognize it as an enduring and cyclic process. Cyclic processes in the urban realm are key for accumulation. In other words, they contribute to the layered production of the urban. This is precisely what mining until today omits: to structurally and explicitly contribute to the production of the environment. Until now, mining has yet to bring nature into culture, consciously developing a post-mining environment. Since mining processes are extremely enduring and layered, it is key to envision the (post-mining)



图例
Key

氰化物与酸性开采废水径流方向
Flows of cyanide and AMD

酸性开采废水径流方向
Flows of AMD

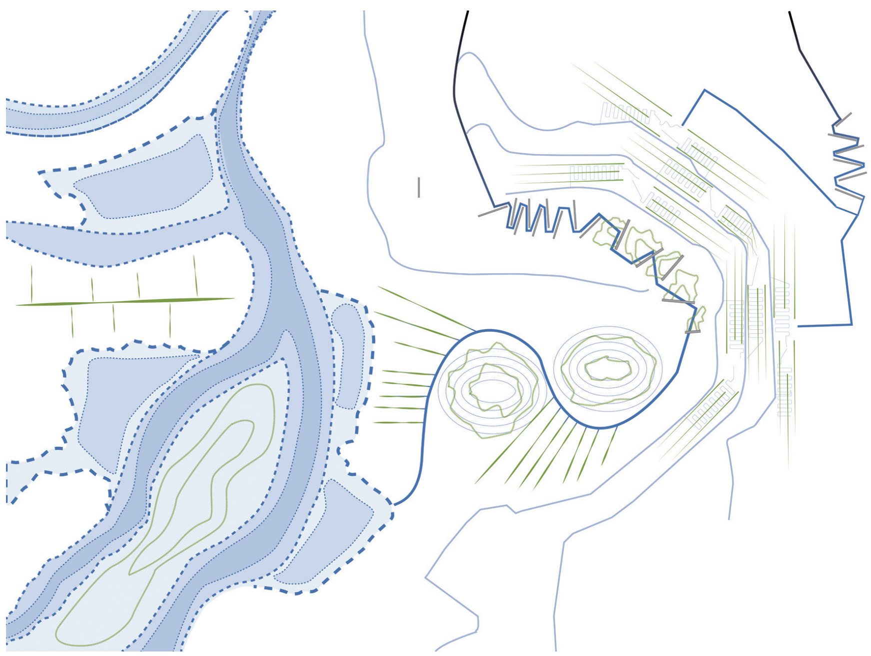
开采运料交通基础设施的水流方向
Water flows based on the haul-road infrastructure

开采运料交通基础设施
Haul-road infrastructure

秘鲁3N国道
3N National road

0 1 2 4km

9 © Batlle i Roig



图例
Key

酸性开采废水
AMD polluted water

不同的冲积平原层
Different floodplains levels

水浸地区
Wet areas

酸性开采废水处理湿地
Wetlands for AMD treatment

高海拔运河
Canals on the high lands

高海拔农业水系
Water system for agriculture on the high lands

中等海拔农业系统分布
Distribution of agricultural system on the middles lands

高海拔农业系统分布
Distribution of agricultural system on the high lands

水浸地区农业
Agriculture in wet areas

0 50 100 200m

10 © Atelier Girot

9. 该研究项目拟将用于运输的道路逐步改造成大型水利基础设施。新的干线道路旨在连接各个水处理流程，同时重新将净化过的水和径流汇入太平洋和亚马逊流域的次级集水区。

10. 在格兰德河上游，通过设计将水引入具有高保水力的“改良土壤”的人工湿地中，使得开采废水在渗入含水层或汇入格兰德河支流之前，能够经过一个缓慢的净化过程，以发挥原始草原的“海绵性能”。

9. The (post-)mining vision entails a progressive transformation of haul roads into large-scale water infrastructures. The new spine aims to articulate water treatment processes while re-directing flows of cleansed water and clean runoff towards the sub-catchments of the Pacific and Amazonas watershed.

10. On the up streams of the Grande River, the design strategy redirects water towards constructed "techno soils" with a high capacity of water retention. In these artificial wetlands, mining effluents go through a slow cleansing process before infiltrating to aquifers or joining the Grande's tributaries, which recovers the Jalca "sponginess."

说，这些过程有助于城市地区的海拔高度上的分层式生产。至今，开采业仍在忽视对环境生产结构进行清晰而明确界定的必要性。因此，目前，开采业仍未将自然视作一种文化，也未曾有意识地对开采后的环境进行规划。所以，鉴于采矿过程旷日持久、涉及因素众多，在矿山开采期间即制定（采后）规划也就变得非常关键——矿山开采与（采后）规划互为因果，相互促进。

这也意味着在周期性规划的采矿过程中，开采和开发是交织在一起的，开采前后并没有截然区别。显然，在这种情况下，后开采景观不可能仅通过将采矿和环境工程简单结合就能实现——这种结合只是对法律义务和规章进行的收效甚微的技术转化——这时，就需要发挥设计的作用了。

但是，采矿工程、环境工程和设计之间存在着结构上的脱节。在以单一专业视角处理矿山景观和对其进行技术修复的过程中，设计被低估为矿山开采后的土地复垦再利用、绿化甚或美化工程。在金属开采过程中，人们既不承认也不利用设计能力来整合各个层面的需求，大量景观构造都未曾经过设计——这阻碍了设计本应在综合生态修复项目中发挥的建设性作用——作为设计的主要成果，空间建构对生态绩效来说也至关重要[49]~[51]。

以卡哈马卡的未来可能性为目标，鲁汶大学完成了一系列针对性的设计研究。正在进行的大规模露天金矿开采的地形塑造过程被设计为一个新的水源管理与人居系统。并且，考虑到生态绩效，审慎的水源地景观（重新）建设需要在亚纳科查的土方工程中融入针对原始草原的多维度设计策略[47]。这也意味着在矿山开采早期就要完成采矿（后）景观的设计，并在开采过程中开始景观构建。具体涉及了在采矿作业期间必须建设的清洁水收集、储存和再分配的基础设施，以为卡哈马卡的较低生态层提供其生态和人居所必需的水源。

研究项目通过设计预景来测试卡哈马卡景观修复的可行性：包括开发一个新的水管理系统，和以一种创新方式在采矿（后）地区排布农业用地。由此，亚纳科查矿区的物料运输基础设施将逐渐转变为水利基础设施，以将清洁雨水引入新的灌溉系统（图9），同时用土工膜覆盖受污染的矿坑，并利用一系列人工湿地处理酸性开采废水（图10）。项目旨在补给水源地含水层，恢复地域整体“海绵性”，以使这片原始草原最终去除毒害，恢复至其可自我维持状态[48]。

environment while extraction processes are ongoing — or so to speak, the one for the other.

In cyclically conceived mining processes, there is not a categorical distinction of before and after, but an intertwined process of extraction and development. It is evident that in such condition, there is no question of a postmining landscape that solely results from mining and environmental engineering logics (which is nothing more than an always unsatisfactory technical translation of legal obligations and regulations). This is, in other words the moment that design comes in.

However, there is a structural disassociation between the endeavors of mining engineering, environmental engineering, and design. The monotechnic fabrication and technical remediation of mining landscapes relegates design practices to the application of land-use recycling, greening, and mere beautification projects of post-mining reclamation. The capacity of design to integrate requirements of various natures is neither acknowledged nor being made use of in processes of metal-mining. Design is absent from the scenes of substantial landscape formation. This prevents the constructive influence of design in comprehensive ecological restoration projects. Spatial configuration — a primary output of design — is, nevertheless, key to ecological performance[49]~[51].

A series of design research was completed at KU Leuven for a possible future of Cajamarca. The ongoing land-forming processes of large-scale, surface goldmining was subverted to also serve as a a new water management and settlement system. Clearly, a thoughtful (re)construction of headwater landscapes requires imbuing Yanacocha's earthworks with a multi-scalar design in respect of the jalcas, linked to its ecological performance[47]. It also implies to design the (post-)mining landscapes already in the early mining stages, and to construct them simultaneously with, and through, exploitation. It surely requires intertwining the development of clean water harvesting, retention, and redistribution infrastructure during the mining operations. Thereby, Cajamarca's lower ecological floors can be provided with water to sustain its ecology and human occupation.

A design scenario tests a possibility for restoring Cajamarca's landscape. It develops a new water management system coupled with a novel manner of organizing agricultural land on (post-) mining areas. The haul-road infrastructure of the Yanacocha mining compound is progressively transformed into water infrastructure that guides clean rainwater to a new irrigation system (Fig. 9), while polluted pits are covered with geomembrane and AMD is treated with a series of constructed wetlands (Fig. 10). The project aims to recharge headwater aquifers and restore an overall "sponginess" to the territory in order that the jalca can eventually return to a non-hazardous, self-sustainable state[48].

采矿（后）景观的规划建设与矿场逐步关停同步进行（图11，12）：对采矿资源（资金、物流、机械、开采工程技术）的调配必须预先考虑采矿后的景观设计、地域规划和逐步建设。这样或许可以更好地保证卡哈马卡水源地的弹性和自可持续性的逐步提升，同时已开采矿点的作业活动也能顺利继续。设计作为一种媒介，不仅可以整合不同专业知识，还可以协调各利益相关者。比如，在此次研究项目中，生态、城市、乡村和矿山之间存在显而易见的利益冲突。当然，从地方到国家再到全球，这些相关者的运作尺度也各不相同。他们关于原则的讨论往往存在冲突，而设计的加入将为之提供长远视角。为了同时实现经济、生态、公平、正义的需求，长远视角往往发挥着决定性作用。**LAF**

致谢

本文使用了约瑟夫·阿萨纳修、尼基塔·沙阿以及格蒂·凡·登布希拍摄 / 绘制的大量照片和图纸，他们均为鲁汶大学城市化与战略规划硕士课程的研究生，并在卡哈马卡调研期间完成了他们的课题论文，作者在此向他们表示感谢！

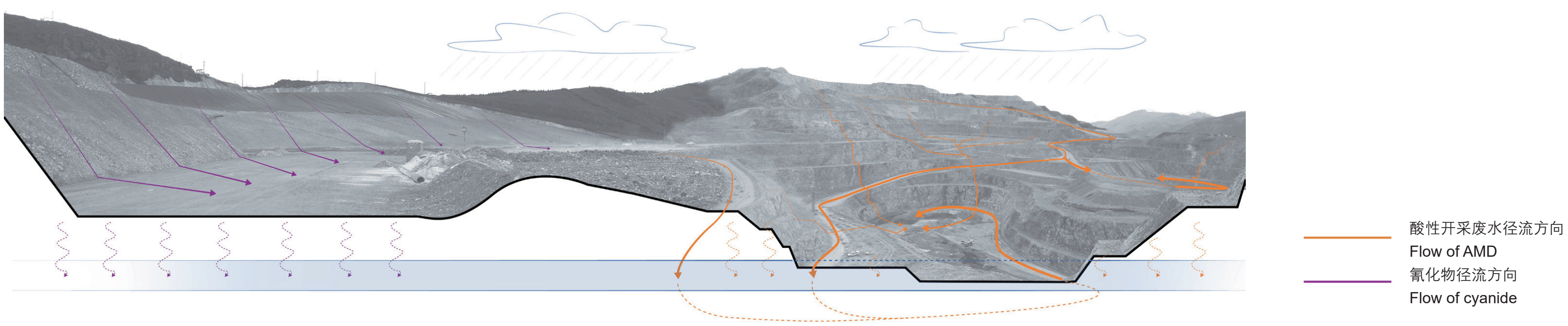
The construction of the (post-)mining landscape is conceived simultaneously with the progressive closure of mining (Fig. 11, 12). The allocation of operative resources of mining (funds, logistics, machinery, and mining engineering expertise) must anticipate the design, territorial planning, and progressive construction of post-mining landscapes. The evolving resilience and self-sustainability of Cajamarca's headwaters might be better ensured while mining activities on sites that are already in exploitation are allowed to continue. Design is a medium that not only allows the integration of different expertise, but also mediates negotiation between different actors. In this case, the contradictory interests of ecology, city, countryside, and mines are evident. Surely, most of these actors also operate on different scales, from the local over the national to the global. By generating design, a projective perspective is added to the often-conflicting discussions on principles between these stakeholders. A projective perspective can make the difference in such discussions. There is no reason that the principles of economy, ecology, fairness, and justice cannot be simultaneously achieved. **LAF**

ACKNOWLEDGEMENTS

The authors would like to thank Iosif Athanasiou, Nikita Shah, and Gertie van den Bosch, three post-grade students in the Master of Urbanism and Strategic Planning program at KU Leuven, who completed their theses in Cajamarca and for use of a number of their photographs and drawings.

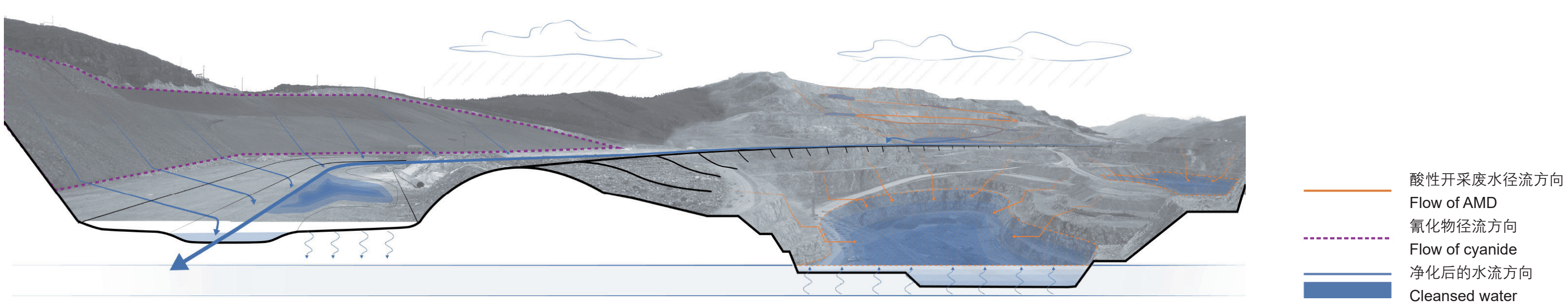
11. 拉奎努阿矿坑现存断面图。目前，拉奎努阿矿坑南段的开采活动在挖掘场地内形成了一系列次级集水区，用于汇集酸性开采废水。
12. 设计后的地形和水流。通过采矿土方工程设计，可使水流逐渐转向并减速。这种新作业策略可使矿场在开采过程中即实现对开采后景观的有意识建设，提前为矿区关停做好准备。

11. Existing profile of the La Quinua Pit. Current mining activities in the south section of the pit form a series of sub-catchments within the excavation site, which allows for the accumulation of AMD.
12. Designed topography and water flows. By choreographing mining earthworks, the design project proposes to progressively redirect and slow down water flows. This new strategy of operations enables mining procedures to take over a conscious construction of post-mining landscapes in anticipation of mining closure.



© I. Athanasiou, 2018

11



© I. Athanasiou, 2018

12

REFERENCES

[1] Millennium Ecosystem Assessment. (2005). Ecosystems and human well-being. https://doi.org/10.1196/annals.1439.003

[2] Albanese, T., & McGagh, J. (2011). Future Trends in Mining. In D, Peter (Ed.). SME Mining Engineering Handbook (pp. 21-36). https://doi.org/10.1007/10_2012_136

[3] Bridge, G. (2004). Contested terrain: Mining and the environment. Annual Review of Environment and Resources, (29), 205-259. https://doi.org/10.1146/annurev.energy.28.011503.163434

[4] Randolph, M. (2011). Current Trends in Mining. In D, Peter (Ed.), SME Mining Engineering Handbook (pp. 11-19). https://doi.org/10.2307/2785453

[5] Peter, D. (2011). Mining: Ancient, Modern, and Beyond. In D, Peter (Ed.), SME Mining Engineering Handbook (pp. 3-9). Colorado: Society for Mining, Metallurgy, and Exploration.

[6] Bryceson, D., & MacKinnon, D. (2012). Eureka and beyond: Mining's impact on African urbanisation. Journal of Contemporary African Studies, 30(4), 513-537. https://doi.org/10.1080/02589001.2012.719376

[7] Contreras, C. (1982). La ciudad del mercurio: Huancavelica, 1570 - 1700. Colección Mínima 13. Lima: Instituto de Estudios Peruanos.

[8] Contreras, C. (1994). La minería en la historia del Perú. América Latina En La Historia Económica, 1(1), 33-40. Retrieved from http://148.207.158.226/index.php/ALHE/article/viewFile/142/205

[9] Hayter, R. (2002). Single Industry Resource Towns. In E. S. Sheppard, & T. J. Barnes (Eds.), A Companion to Economic Geography (pp. 290-307). Los Angeles: Blackwell Publishers. https://doi.org/10.1111/b.9780631235798.2002.x

[10] Rudolph, W. E. (1936). The Lakes of Potosi. Geographical Review, 26(4), 529–554. doi: 10.2307/209714

[11] Godoy, R. A. (1985). Technical and Economic Efficiency of Peasant Miners in Bolivia. Economic Development and Cultural Change, 34(1), 103–120. https://doi.org/10.1086/451511

[12] Villena, G. L. (1949). Las minas de Huancavelica en los siglos XVI y XVII. Sevilla: Escuela de Estudios Hispano-Americanos de Sevilla.

[13] Brading, D. A., & De Zaionz, M. Z. (1971). Las minas de plata en el Perú y México colonial. Un estudio comparativo. Desarrollo Económico, 11(41), 101-111. doi:10.2307/3466185

[14] Von Humboldt, A., Bohn, H. G., & Otté, E. C. (1850). Views of nature: On contemplations on the sublime phenomena of creation. London: HG Bohn.

[15] Godoy, S. O. P. (1993). Vivir y morir en el mineral de Hualgayoc a fines de la colonia. Jahrbuch Für Geschichte Lateinamerikas = Anuario de Historia de América Latina (JbLA), (30), 75-127.

[16] Vega, M. (1827). Memoria de las minas de las provincias de Gualgayoc, Caxamarca y Huamachuco, sobre la localidad del cerro mineral de Hualgayoc y los demás de la provincia de Chota, la calidad de sus metales e ingenios donde se muelen, número de las minas, modo de beneficiarlas y de las demás producciones y poblaciones. Lima: Imprenta de Santa Rosa. https://doi.org/10.1016/0003-6870(73)90259-7

[17] Contreras, C. (1995). Los mineros y el rey: Los Andes del norte, Hualgayoc 1770-1825. Perú: Instituto de Estudios Peruanos.

[18] Soule, E. B. (2014). The Bishop's Utopia. Envisioning Improvement in Colonial Peru. Philadelphia: University of Pennsylvania Press.

[19] Buytaert, W., Célleri, R., De Bièvre, B., Cisneros, F., Wyseure, G., Deckers, J., & Hofstede, R. (2006). Human impact on the hydrology of the Andean páramos. Earth-Science Reviews, 79(1-2), 53-72. https://doi.org/10.1016/j.earscirev.2006.06.002

[20] Murra, J. V. (1972). El control vertical de un máximo de pisos ecológicos en la economía de las sociedades andinas. Huánuco: Universidad Nacional Hermilio Vardizán.

[21] Elizalde, B., Whellams, M., & Sabater, C. (2007). Reseña de las relaciones de Newmont con la comunidad: Mina de Yanacocha, Perú. Retrieved from https://www.newmont.com/wp-content/uploads/2019/05/CRR-Yanacocha-Report-Spanish.pdf

[22] Watkins, M. (2018). Unsettling the Mining Frontier. In P. Bélanger (Ed.), Extraction empire: 2017-1217, undermining the systems, states, & scales of Canada's global resource empire (pp. 34-57). Cambridge: MIT Press.

[23] McKenzie, F. H. (2010). Fly-in fly-out: The challenges of transient populations in rural landscapes. In G. W. Luck, D. Race, & R. Black (Eds.), Demographic Change in Australia's Rural Landscapes (pp. 353-374). Dordrecht: Springer.

[24] Steel, G. (2013). Mining and Tourism: Urban Transformations in the Intermediate Cities of Cajamarca and Cusco, Peru. Latin American Perspectives, 40(2), 237-249. https://doi.org/10.1177/0094582X12468866

[25] Instituto Nacional de Estadistica e Investigación. (2017). Perú: Crecimiento y distribucion de la poblacion. Retrieved from https://www.inei.gob.pe/media/MenuRecursivo/publicaciones_digitales/Est/Lib1530/libro.pdf

[26] SEDACAJ. (2019). Plan Maestro Optimizado Quinquenio 2019-2023. Retrieved from http://www.sunass.gob.pe/websunass/index.php/eps/estudios-tarifarios/planes-maestros-optimizados-pmo/doc_details/3387-eps-sedacaj-s-a-pmo-2019-2023

[27] Bridge, G. (2004). Mapping the bonanza: Geographies of mining investment in an era of neoliberal reform. The Professional Geographer, 56(3), 406-421. https://doi.org/10.1111/j.0033-0124.2004.05603009.x

[28] Presidencia del Consejo de Ministros. (2011). Decreto Supremo No 093-2011-PCM. Diario El Peruano. Retrieved from http://www.pcm.gob.pe/transparencia/Resol_ministeriales/2011/DS-093-2011-PCM.pdf

[29] Gold Fields. (2014). Cerro Corona Mine. Retrieved from http://www.goldfields.com/reports/rr_2009/tech_cerro.php

[30] Minera San Cristóbal S.A. (2016). About Minera San Cristóbal S.A. Retrieved from https://www.minerasancristobal.com/v3/en/inicio/operations/

[31] Younger, P. L., Banwart, S. A., & Hedin, R. S. (2002). Mine Water: Hydrology, Pollution, Remediation. Dordrecht: Kluwer Academic Publishers. https://doi.org/10.1007/978-94-010-0610-1_3

[32] Gobierno de la República del Perú. (2018, July 19). Ministerio del Ambiente y de Energía y Minas informan en Hualgayoc la asignación presupuestal para la remediación de pasivos ambientales mineros. Retrieved from https://www.gob.pe/institucion/minam/noticias/16918-ministerios-del-ambiente-y-de-energia-y-minas-informan-en-hualgayoc-la-asignacion-presupuestal-para-la-remediacion-de-pasivos-ambientales-mineros

[33] Robb, G. A., & Robinson, J. D. F. (1995). Acid Drainage from Mines. The Geographical Journal, 161(1), 47-54. doi:10.2307/3059927

[34] University of Wyoming. Office of Research. (2006). Handbook of western reclamation techniques. Wyoming. Denver: Western Regional Coordinating Center, Office of Surface Mining Reclamation and Enforcement.

[35] Bradshaw, A. D. (1983). The reconstruction of ecosystems. Journal of Applied Ecology, (20), 1-17. doi:10.2307/2403372

[36] Séré, G., Schwartz, C., Ouvrard, S., Sauvage, C., Renat, J. C., & Morel, J. L. (2008). Soil construction: A step for ecological reclamation of derelict lands. Journal of Soils and Sediments, 8(2), 130-136. https://doi.org/10.1065/jss2008.03.277

[37] Strosnider, W. H. J., López, F. S. L., & Nairn, R. W. (2011). Acid mine drainage at Cerro Rico de Potosí I: Unabated high-strength discharges reflect a five century legacy of mining. Environmental Earth Sciences, 64(4), 899-910. https://doi.org/10.1007/s12665-011-0996-x

[38] Bradshaw, A. (2000). The use of natural processes in reclamation - advantages and difficulties. Landscape and Urban Planning, 51(2-4), 89-100. https://doi.org/10.1016/S0169-2046(00)00099-2

[39] MYSRL. (2007). Centro Experimental para el Cierre de Minas Maqui Maqui. Retrieved from https://www.snmpe.org.pe/repositorio-premio-al-desarollo-sostenible/80-2007/4290-centro-experimental-para-el-cierre-de-minas-maqui-maqui.html

[40] MYSRL. (2008). Reservorio San José. Retrieved from http://www.yanacocha.com/wp-content/uploads/Reservorio-San-Jose.pdf

[41] MYSRL. (2010). Actualización del Plan de Cierre de Minas para las Instalaciones de Minera Yanacocha. Retrieved from https://studylib.es/doc/6054685/resumen---ministerio-de-energ%C3%ADa-y-minas

[42] MYSRL. (2006). Plan de gestión ambiental. Estudio de impacto ambiental Proyecto Suplementario Yanacocha Oeste (pp. 427-522). Retrieved from http://www.minem.gob.pe/descripcion.php?idSector=4&idTitular=1194

[43] PBS.org, & New York Times. (2005, October). Peru — The Curse of Inca Gold. Retrieved from http://www.pbs.org/frontlineworld/stories/peru404/

[44] Breitenbach, A. J. (2005). Heap leach pad design and construction practices in the 21th century. Retrieved from http://www.ore-max.com/pdfs/resources/heap_leach_pad_design_and_construction_practices_in_the_21st_century.pdf

[45] Palmer, M. A., Bernhardt, E. S., Schlesinger, W. H., Eshleman, K. N., Foufoula-Georgiou, E., Hendryx, M. S., ... & Wilcock, P. R. (2010). Mountaintop Mining Consequences. Science and Regulation, 327(5962), 148-149. doi:10.1126/science.1180543

[46] Walker, L. R., Walker, J., & Hobbs, R. J. (2007). Linking Restoration and Ecological Succession. doi:10.1007/978-0-387-35303-6

[47] Bauer, A. M. (1965). Simultaneous Excavation And Rehabilitation Of Sand And Gravel Sites. Retrieved from: https://www.ideals.illinois.edu/bitstream/handle/2142/27924/simultaneousexca01baue.pdf?sequence=1

[48] Ballantyne, P. (2001). Unsettled country: Reading the Australian ghost town. Journal of Australian Studies, 25(70), 33-38. https://doi.org/10.1080/14443050109387703

[49] Corner, J. (2003). Landscape Urbanism. In M. Mostafatavi & C. Najle (Eds.), Landscape urbanism: a manual for the machinic landscape (p. 176). London: Architectural Association.

[50] Corner, J. (2006). Terra Fluxus. In C. Waldheim (Ed.), The Landscape Urbanism Reader (pp. 22-35). New York: Princeton University Press.

[51] Waldheim, C. (2016). Landscape urbanism: A general theory. New Jersey: Princeton University Press.

[52] Pollack, L. (2006). Constructed Ground: Questions of Scale. In C. Waldheim (Ed.), The Landscape Urbanism Reader (pp. 126-141). New York: Princeton University Press.

[53] Athanasiou, I. (2018). Territorial Sponge and Battery. Reclaiming headwaters in a disfigured landscape (Unpublished master's thesis). KU Leuven University, Leuven.